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Grande Rivière de la Baleine, Hudson Bay, Quebec — 1000 years of sedimentation[1]

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Abstract: The sedimentology of five box cores and four gravity cores taken within 12 km of the mouth of Grande Rivière de la Baleine is presented with particular focus on the character and thickness of late Holocene sedimentation. Huntec seismic records show that 10 to 30 m of postglacial sediment have been deposited near the river mouth, implying sedimentation rates during the Holocene of 1.3 to 4 mm/a. All available cores sampled the surficial fluviodeltaic facies at the top of the Late Quaternary lithostratigraphic section. Late Holocene sedimentation rates within this facies are constrained by a new radiocarbon date of 1280 ± 40 BP. Core sedimentology, grain-size analyses, and X-radiography indicate that the sediments consist of olive-grey mud that has undergone some degree of bioturbation, but that is not burrow homogenized. The cores thus have the potential to preserve some decade-scale paleoenvironmental information.

Résumé : Les auteurs décrivent la sédimentologie de cinq carottes prélevées par carottier à boîte et de quatre carottes prélevées par carottier à gravité à moins de 12 km de l'embouchure de la Grande Rivière de la Baleine, notamment la nature et l'épaisseur des sédiments de l'Holocène supérieur. Selon des profils sismiques Huntec, entre 10 et 30 m de sédiments postglaciaires ont été déposés près de l'embouchure de la rivière, faisant supposer que les taux de sédimentation ont varié de 1,3 à 4 mm/a pendant l'Holocène. Toutes les carottes disponibles contenaient le faciès fluviodeltaïque superficiel du sommet de la coupe lithostratigraphique du Quaternaire supérieur. Les taux de sédimentation à l'Holocène supérieur dans ce faciès ont été établis au moyen d'un nouvel âge radiocarbone de 1280 ± 40 B.P. L'étude sédimentologique des carottes, des analyses granulométriques et la radiographie par rayons X indiquent que les sédiments consistent en une boue gris olive qui a subi une certaine bioturbation, mais qui n'a pas été complètement uniformisée par la formation de terriers. Les carottes peuvent donc renfermer des sédiments qui ont conservé certains renseignements paléoenvironnementaux d'échelle décennale.

[1] Contribution to PERD

INTRODUCTION

The study area is located at the southeastern end of Hudson Bay, up to 12 km from the mouth of Grande Rivière de la Baleine (Fig. 1). Boomer seismic-reflection data collected with the Huntec DTS system in 1992 (Amos et al., 1993) show a postglacial sediment thickness of 10 to 30 m within the study area. The seismostratigraphy and lithostratigraphy of these sediments are presented in Bilodeau et al. (1990), Gonthier et al. (1993), and Zevenhuizen (1996). Bedrock is overlain by four acoustic and sedimentary facies: 1) ice-contact sediments interpreted as glacial till; 2) rhythmically bedded mud interpreted as glaciolacustrine mud; 3) postglacial marine mud; and 4) an areally confined fluviodeltaic facies immediately seaward of the river mouth recognized only by Gonthier et al. (1993). Not all stratigraphic units are everywhere present throughout the study area. These acoustic facies are illustrated in a Huntec DTS seismic section from data collected by Amos et al. (1993) (Fig. 2).

Five box cores and four gravity cores within 12 km of the mouth of Grande Rivière de la Baleine were re-examined to look at late Holocene fluviodeltaic sedimentation, particularly within the past 1 ka (Table 1). Box core 92028H-027 was selected as representative of the suite of cores and was X-radiographed and subsampled at 1 cm intervals for grain size. The objectives of this paper are 1) to place the cores from the mouth of Grande Rivière de la Baleine within the pre-existing seismostratigraphy and lithostratigraphy of the region, 2) to define the lithology and facies of late Holocene sediments from the cores, 3) to quantify late Holocene sedimentation rates, and 4) to determine the suitability of box core 92028H-027 for identifying decade-scale patterns of sedimentation.

METHOD

A total of five box cores and four gravity cores (Table 1), collected from the mouth of Grande Rivière de la Baleine (Amos et al., 1993), were assessed for their suitability for identifying decade- and century-scale change. Seven of these cores were redescribed; radiocarbon dates from two additional cores were also used in this study. Of the re-examined cores, a shell from 141 cm in gravity core 92028H-009 was subsampled for AMS radiocarbon dating. On the basis of visual observations of box cores, 92028H-027 was selected for further analyses because it appeared the least bioturbated. Colour was measured at

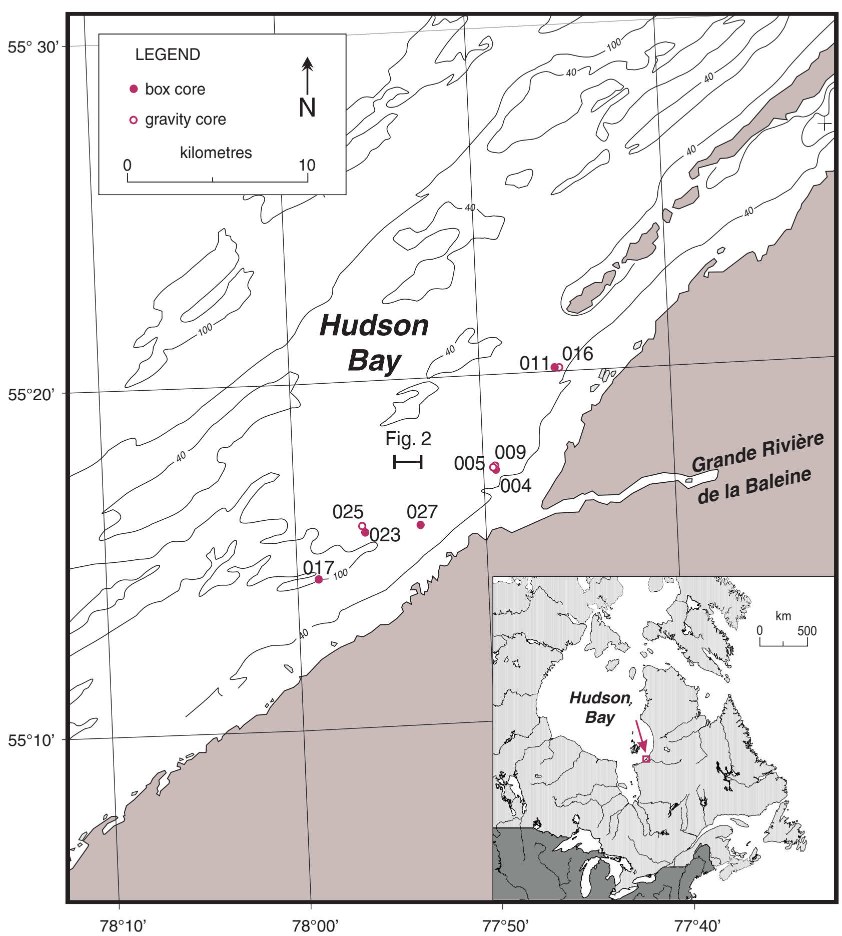

Figure 1.

Study area showing re-examined box cores and gravity cores and location of Huntec seismic profile. Depths in metres.

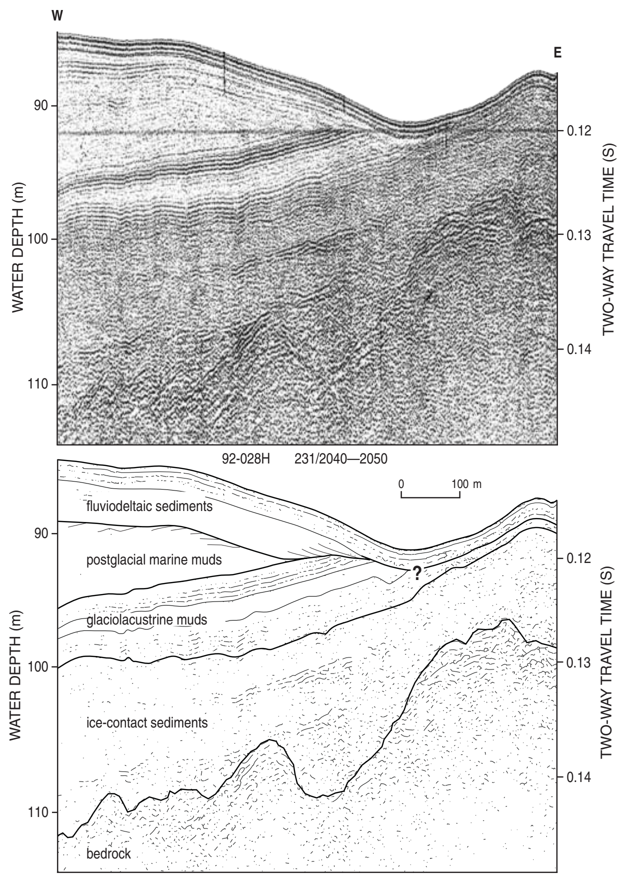

Figure 2. *Acoustic and stratigraphic facies interpretation of Gonthier et al. (1993) on Huntec data collected by Amos et al. (1993). Refer to Figure 1 for location.*

1 cm intervals with a Minolta CM-2002 spectrophotometer. The core was then slabbed, X-radiographed, and subsampled for grain size at 1 cm intervals. Samples were wet sieved at 63 µm and weight percentages were obtained for the >63 µm fraction. The size distribution of the <63 µm sample fraction was analyzed using a model TA II Coulter Counter.

STRATIGRAPHY

Laurentide ice, which occupied southern Hudson Bay during the Late Wisconsinan glaciation, deposited a discontinuous layer approximately 5 m thick of diamicton over bedrock (Bilodeau et al., 1990; Gonthier et al., 1993; Zevenhuizen, 1996). These ice-proximal or ice-contact deposits are conformably overlain by acoustically stratified and rhythmically bedded clays and silts that reach a maximum thickness of 5 m. On the basis of microfaunal and palynological evidence, these sediments are >8.0 ka (radiocarbon years BP) and probably record Glacial Lake Ojibway (Bilodeau et al., 1990). Glaciolacustrine sediments are conformably overlain by weakly acoustically stratified postglacial marine muds deposited during the invasion of the Tyrrell Sea, beginning at ca. 8.0 ka (Bilodeau et al., 1990) and by bioturbated, olive-grey, modern marine mud. These postglacial marine muds are <5 m thick in the nearshore (Gonthier et al., 1993). Within 11 km of the mouth of Grande Rivière de la Baleine, postglacial marine muds with relatively transparent acoustic character are conformably overlain by a unit with high-amplitude, subparallel reflections with an average thickness of 15 m. Gonthier et al. (1993) interpreted this unit as a deltaic constructional wedge.

Table 1. Summary of studied cores.

Core number	Core type	Latitude °N	Longitude °W	Water depth (m)	Core length (cm)	Chronology
92028H-004	box core	55°17.28'	77°49.38'	60	41	
92028H-005	gravity core	55°17.35'	77°50.12'	60	126	
92028H-009	gravity core	55°17.37'	77°49.45'	61	321	^{14}C
92028H-011	box core	55°20.15'	77°46.06'	58	31	
92028H-016	gravity core	55°20.15'	77°45.82'	53	260	^{14}C
92028H-017	box core	55°14.35'	77°58.91'	96	49	
92028H-023	box core	55°15.64'	77°56.37'	86	51	
92028H-025	gravity core	55°15.83'	77°56.52'	77	482	^{14}C
92028H-027	box core	55°15.79'	77°53.45'	79	48	

The cores re-examined in this study were placed into the regional stratigraphic framework of Gonthier et al. (1993) on the basis of Huntec DTS seismic and 3.5 kHz data of Amos et al. (1993) and core stratigraphy (Fig. 3). All cores record the deltaic constructional wedge of Gonthier et al. (1993), which from visual logging descriptions, consists predominantly of olive-grey bioturbated mud with isolated granules and shell fragments. Gravity cores 009 and 016 also display distinctly laminated to thin-bedded intervals, defined by colour and texture, up to 38 cm thick. In gravity core 009, the lower laminated interval beginning at 262 cm records rhythmically bedded sediments beneath fluviodeltaic deposits (Zevenhuizen, 1996). This is confirmed by 3.5 kHz data, which show that gravity core 009 was taken beside a topographic high that may have led to local winnowing, precluding the deposition of postglacial marine muds. Box cores 023 and 004 contain significant amounts of disseminated sand within mud in the surficial 10 cm only. Acoustic 3.5 kHz profiles show that core 023 is positioned next to a high; winnowing associated with the location of this core may account for the increase in sand content at the surface.

BOX CORE 92028H-027

Box core 92028H-027 was selected for further analyses to characterize the late Holocene sedimentary facies near the mouth of Grande Rivière de la Baleine (Fig. 4). From visual observation, the core consists of partially bioturbated olive-grey mud and appears less bioturbated than the other box cores from near the river mouth. X-radiography confirms that the core has been bioturbated, although remnant bedding is still visible at 12 cm and 17 cm.

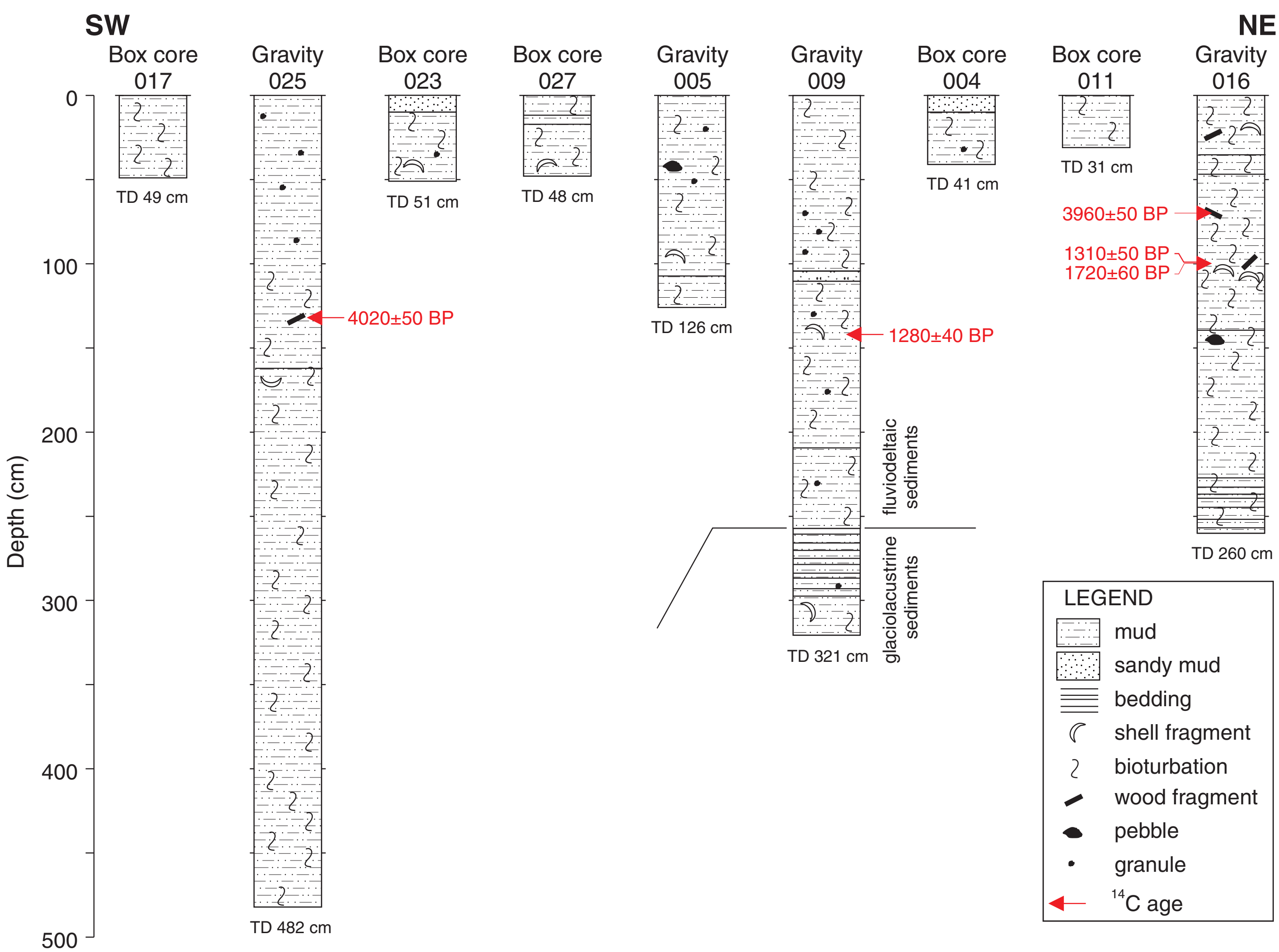

Figure 3. Cruise 92028H cores used for this study. All cores record the fluviodeltaic facies of Gonthier et al. (1993) with the exception of gravity core 009, which also records glaciolacustrine sediments. Marine radiocarbon ages are reported in radiocarbon years with a -410 year reservoir correction applied. TD = total depth

Grain-size data for box core 92028H-027 are presented in Figures 5 and 6. The >63 µm fraction was wet sieved and is presented as a percentage of the weight of the total sample. The 1 to 2 µm, 2.52 to 20.2 µm, and 25.4 to 40.3 µm volume fractions were normalized with the >63 µm weight fraction to 100%. Data on the <1 µm fraction and channel particle counts <10 were not included in modal or percentage and volume calculations.

Downcore grain-size distributions for the <63 µm fraction are interpreted to represent settling from both flocculated and unflocculated suspensions after the model of Kranck (1986) and Kranck et al. (1996). Those spectra with a well developed mode (such as the grain-size distribution at 1 cm) depict 'one round' sediments that have settled from an unsorted, unflocculated suspension with limited erosion or resuspension (Kranck et al., 1996). The relatively flat slope of these spectra between 1 and 3 µm represents the flocculated component of the distribution. A change in slope of these finer distributions occurs between 38 to 30 cm and 7 cm to the top of the core. Kranck et al. (1996) believed variability of the slope of the fine-grained limb to be a function of source material. River floodplains, deltas, and tidal flats are some environments containing 'one round' sediment distributions (Kranck et al., 1996). Spectra with a poorly defined mode (such as the grain-size distribution at 39 cm) probably represent settling from a totally flocculated suspension resulting in the deposition of poorly sorted mud (Kranck, 1986). The predominance of these flocculated spectra in box core 92028H-027 may indicate distal fluvial deposition given that the box core is from 6 km west of the river mouth. The data in Figure 6 also show an overall downcore decrease in the weight per cent of the >63 µm fraction of the samples beginning at 8 cm. The modal diameter of the <63 µm sediment fraction shows a slight increase below 22 cm.

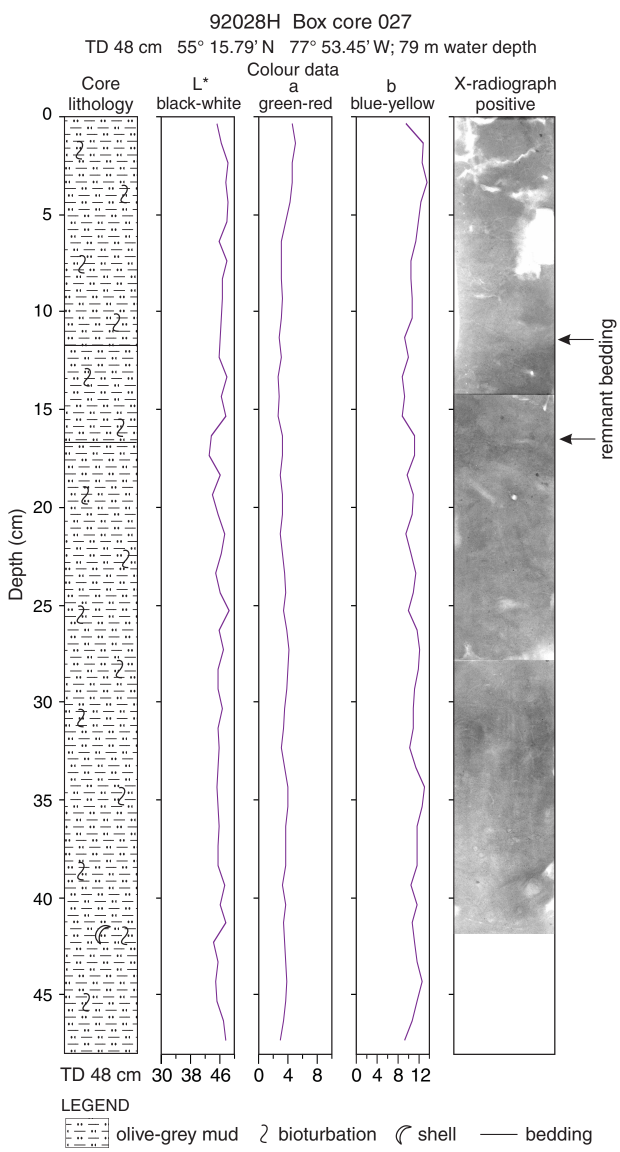

Figure 4. Summary plot for box core 92028H-027. Colour L a b system described in Giosan et al. (in press). TD = total depth*

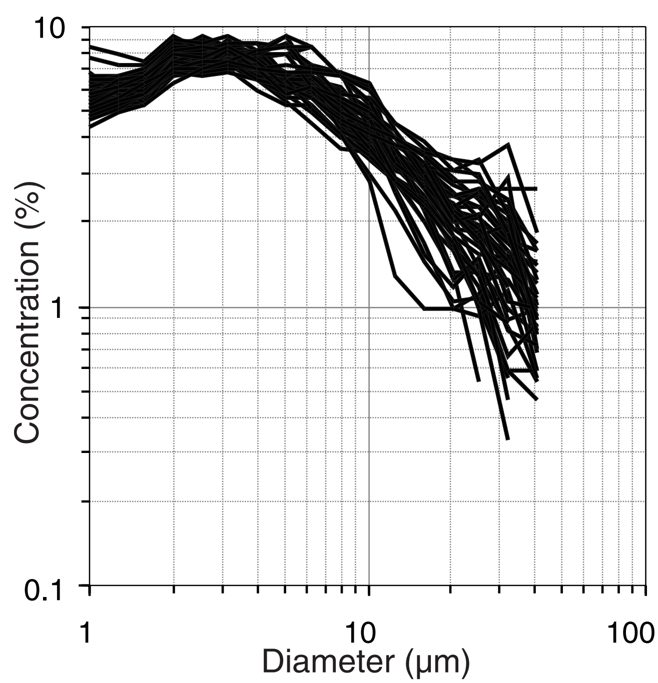

Figure 5. Grain-size distributions for samples 1 to 42 plotted on the same axis.

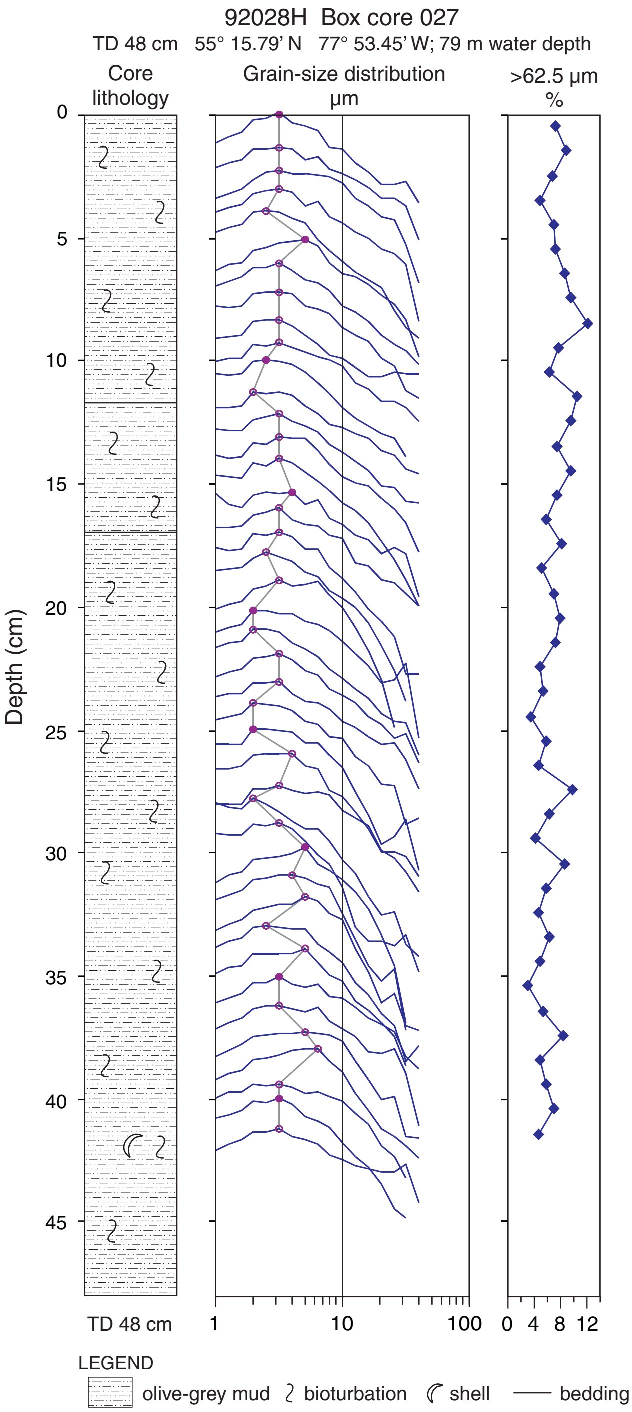

Figure 6. Grain-size distributions plotted downcore with modal size superimposed on the distributions as a continuous line. TD = total depth

CHRONOLOGY

Huntec seismic data show 10 to 30 m of postglacial sediment accumulation near the mouth of Grande Rivière de la Baleine. Using the chronology of Gonthier et al. (1993) of about 8000 BP for the onset of postglacial sedimentation, this suggests a mean Holocene sedimentation rate of 1.3 to 4 mm/a. Late Holocene sedimentation rates are constrained by two marine radiocarbon ages from gravity cores 009 and 016. A previously unreported date of 1720 ± 60 BP (marine radiocarbon ages in radiocarbon years with a -410 year reservoir correction applied; note that this reservoir correction may be too small) was measured on an undetermined but paired bivalve interpreted as in situ. A new date of 1280 ± 40 BP has been obtained on an unidentified single valve (Table 2, Fig. 3). On the basis of these shell dates, we interpret at least the two older wood dates as representing old reworked material. From shell dates, late Holocene sedimentation rates at the mouth of Grande Rivière de la Baleine are as high as 1 mm/a at gravity core site 009, diminishing to 0.6 mm/a northeast of the river mouth at gravity core site 016. If the reservoir correction has been underestimated, then sedimentation rates would also have been underestimated.

DISCUSSION

On the basis of acoustic data and core stratigraphy, box and gravity cores used in this study record the deltaic constructional sediments of Gonthier et al. (1993). Gonthier et al. (1993) inferred that this deltaic sedimentation began at about 3.5 ka on the basis of a radiocarbon date of 3810 ± 50 BP (TO-1099) reported by Bilodeau (1990) for marine shells immediately overlying deltaic sands exposed in the present river bank. Older glaciolacustrine sediments were observed in our study only at the base of gravity core 009. Radiocarbon ages on marine shells back to 1720 ± 60 BP constrain sedimentation rates to between 0.6 mm/a at the northeast end of the study area and 1 mm/a at a location 3 km seaward of the river mouth. For comparison, ^{210}Pb activity measurements from cores taken 7 km seaward of the river mouth and 26 km farther offshore returned sedimentation rates of 0.5 and 0.6 mm/a, respectively (d'Anglejan and Biksham, 1988). Gonthier et al. (1993) identified two 10 to 30 m thick fluviodeltaic sediment lobes immediately southwest and northeast of the river channel axis that may record sedimentation rates at least three times higher than those reported from core 009 near the channel axis. Three kilometres offshore, the particle flux during breakup and early summer was an

Table 2. Radiocarbon dates from gravity and box cores.

Core number	Sample depth (cm)	Age (radiocarbon years BP)[1]	Laboratory number	Material
92028H-009	141	1280 ± 40	Beta-163480	shell
92028H-016	70	3960 ± 50	TO-3592	wood
92028H-016	99	1310 ± 50	TO-3593	wood
92028H-016	101	1720 ± 60	TO-3594	shell
92028H-025	132	4020 ± 50	TO-3595	wood

[1]-0.4 ka reservoir correction applied for shells only

order of magnitude greater than at offshore stations (d'Anglejan and Biksham, 1988). The seaward reduction in sedimentation rates from 1 to 0.5 mm/a between 3 km and 7 km and the potentially higher sedimentation rates within the fluviodeltaic sediment lobes suggest that most sediment from Grande Rivière de la Baleine is deposited within 5 km of the shoreline.

The results of X-radiography, grain-size analyses from box core 92028H-027, and the new chronology for the study area indicate that although the sediment is bioturbated, remnant bedding and grain-size trends may represent changes on a scale of a few decades to a century. Remnant bedding in box core 92028H-027 occurs between 17 and 12 cm and falls within the interval of increasing weight per cent of the >63 µm sediment fraction (between 42 and 8 cm). Using an average sedimentation rate of 0.8 mm/a for the study area, these remnant beds may record more rapid periods of sedimentation 210 to 150 years ago. The overall upcore increase in the >63 µm fraction to 8 cm is probably a response to forced regression resulting from glacio-isostatic uplift. The overall decrease in the weight per cent of the >63 µm fraction of the samples that began at 8 cm or 100 years ago and has continued to the present is unexplained. It is not possible to recognize individual annual sedimentation packets and it is uncertain how much of the sediment column may have been deposited during major flood events. Thus, further work is needed to extract decade-scale resolution from the cores.

CONCLUSIONS

The following conclusions can be made from this study.

1. The nine cores used in this study record the fluviodeltaic sediments of Gonthier et al. (1993). Gravity core 009 also intersects underlying glaciolacustrine deposits.
2. In core, the fluviodeltaic facies consists of olive-grey bioturbated mud that is composed predominantly of very fine silt.
3. A new marine radiocarbon age of 1280 ± 40 BP from the fluviodeltaic sediments, combined with an existing age of 1720 ± 60 BP gives an average sedimentation rate of 0.8 mm/a for late Holocene sedimentation in the study area.
4. Remnant bedding and grain-size spectra suggest that the sediments from box core 92028H-027 can be used to identify isolated depositional change on a scale of decades to a century.

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